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Woernle, C M ; Burkhardt, J K ; Bellut, D ; Krayenbuehl, N ; Bertalanffy, H

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Do Iatrogenic Factors Bias the Placement of External Ventricular Catheters? —A Single Institute Experience and Review of the Literature—

Christoph M. WOERNLE,[1] Jan-Karl BURKHARDT,[1] David BELLUT,[2] Niklaus KRAYENBUEHL,[1] and Helmut BERTALANFFY[1]

Departments of [1]Neurosurgery and [2]Neuroradiology, University Hospital Zurich, Zurich, Switzerland

Abstract

Placement of external ventricular drainage (EVD) catheters is the gold standard for managing acute hydrocephalus, but the range of complications varies in different studies. The objective of this present single institute study is to analyze iatrogenic factors, which may influence the EVD device placement and the patient's outcome. A total of 137 EVD placements in 120 patients at the University Hospital Zurich were analyzed retrospectively. Discriminative findings between the pre- and postoperative imaging were obtained and evaluated in detail with regards to the postoperative course, ventriculostomy-related infection, and acute neurological deterioration directly related to the EVD placement. These findings were correlated to iatrogenic factors including education level of the neurosurgeon and surgical setting. Overall EVD-related complication rate was 16.1%, including infection rate of 10.2%, catheter malplacement rate of 2.2%, and hemorrhage rate of 3.6%. Although not statistically significant, catheter-associated hemorrhages and malplacements were found mostly in primary EVD surgery, with a higher complication rate associated with junior residents as the performing surgeon. In contrast, ventriculostomy-related infection was most likely present in patients with more than one EVD placement and in patients treated by more experienced physicians. Complications related to EVD are common. The rate and character of the complication depends on the education level of the surgeon.

Key words: external ventricular drainage, hydrocephalus, neurosurgery, iatrogenic factor, complication

Introduction

Ventriculostomy followed by drainage of the cerebral fluid extracorporally (EVD) represents the neurosurgical ''gold standard'' management of acute hydrocephalus and intracranial hypertension.[15,18] Since the first ventricular puncture was introduced to clinical practice by Walter Dandy in 1918,[4] a variety of surgical techniques and different modifications for the placement of external devices have been described.[8,20] The surgical approaches for ventriculostomy were controlled by Kocher's craniometer.[1] Although the surgical procedure is standardized, perioperative complications such as infection, iatrogenic related hemorrhages, or catheter malplacements are well known (Table 1).[3,5,6,8,10,12,15–21] In particular, EVD-associated infections were found in 0% to 20% of patients in previous studies (Table 1), and the risk of surgery-associated hemorrhages or EVD device malplacements are often described.[3,5,6,10,12,15–21] The highest reported complication rate of 33% shows the possible understatement of the catheter-associated complication risk.[15] The question still remains why this variety of perioperative complications is found and whether iatrogenic factors influence the surgical complication rate and thus the outcome. EVD devices are usually not placed with neuroimaging-based navigation, but based on typical anatomical landmarks.[1,11] This condition generates the balancing act between the quite simple procedure and the risk of severe complications.

The present study analyzed and interpreted the in-

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Table 1 Previous published studies of complications of external ventricular drainage (EVD) placement

Author (Year)	No. of patients	Diagnosis	Complications	%
Roitberg et al. (2001)[17]	103	p/s act.H	hemorrhage	1.9
			infection	1.0
Zabramski et al. (2003)[21]	206	CSF diversions	infection with rifampin/minocycline	17.6
			infection without rifampin/minocycline	36.7
Anderson et al. (2004)[1]	63	TBI	hemorrhage	12.0
			infection	1.5
			malplacement	8.8
Maniker et al. (2006)[15]	160	CD, TBI, p.H, TU	hemorrhage	33.0
Kakarla et al. (2008)[12]	346	CD, SAH, TBI	hemorrhage	5.0
			infection	13.0
Beer et al. (2008)[3]*	—	—	infection	5.0–20.0
Ngo et al. (2009)[16]	66	TBI, p.H	overall	26.0
			hemorrhage	4.2
			infection	9.4
			malplacement	6.3
Saladino et al. (2009)[18]	138	CSF diversions	hemorrhage	7.1
			infection	3.3
			malplacement	12.3
Gardner et al. (2009)[6]	188	CSF diversions	hemorrhage	41.0
			hemorrhage (>15 cm^3)	19.0
Ehtisham et al. (2009)[5]	29	CSF diversions	overall	20.7
			hemorrhage	20.7
			infection	0.0
Scheithauer et al. (2009)[19]	1333	CSF diversions	meningitis/ventriculitis	8.6

*Review of the literature, Medline 1990–2008. CD: cerebrovascular disease, CSF: cerebrospinal fluid, p.H: primary hydrocephalus, p/s act.H: primary/secondary acute hydrocephalus, SAH: subarachnoid hemorrhage, TBI: traumatic brain injury, TU: tumor.

fluence of iatrogenic factors in EVD placements, with major attention on the EVD procedure, EVD devices, educational level of the neurosurgeon, and the operation setting.

Patients and Methods

A retrospective analysis was performed of 120 consecutive patients, 65 females (54%) and 55 males (46%) aged from 2 to 89 years (median 49 years), treated between August 2007 and June 2009 at the Department of Neurosurgery, University Hospital Zürich with EVD for acute hydrocephalus or increased intracranial pressure. A total of 137 EVD placements were performed by neurosurgeons of our center. The admitting diagnosis included a large group with cerebrovascular diseases (n = 87, 73%), as well as general nonventriculostomy-related infections (n = 7, 6%), traumatic brain injuries (n = 7, 6%), primary hydrocephalus (n = 11, 9%), and neoplastic diseases (n = 8, 7%).

Iatrogenic factors analyzed in this study were defined as the experience of the neurosurgeon in charge (junior resident [JR], 1st to 2nd year of residency; senior resident [SR], 3rd to 6th year of residency; or attending [AT], staff/faculty neurosurgeon), and the environment where the procedure was performed (general ward, emergency room, intensive care unit [ICU], or operating room [OR]).

Complications related to the EVD placement were defined as malplacement of the ventricular catheter, intracerebral hemorrhage, and ventriculostomy-related infection. Ventriculostomy-related infection was diagnosed via microbiological analyses as previously described.[21] This uniform definition is based on the recommendations of the Centers for Disease Control and Prevention (Atlanta, Georgia, USA).[9] Malplacement and hemorrhage were detected by computed tomography (CT). Any changes between the pre- and postoperative CT scans were analyzed in detail. New lesions projected as hyperdensity on the CT scan in direct contact with the EVD trajectory line were defined as iatrogenic bleeding. Hence, any new intraparenchymal, intraventricular, sub-

dural, and/or subarachnoidal hemorrhage >0.5 cm^3 was identified and recorded. Malplacement was defined as the EVD tip outside the lateral cerebral ventricle system. In the postoperative course, cerebrospinal fluid (CSF) infection and acute neurological deterioration in direct coherence with the EVD placement were also evaluated. If replacement of a catheter was needed, the same burr hole was used in this series.

Statistical analysis was performed using Microsoft Excel (Microsoft Corp., Redmond, Washington, USA) and SPSS Statistic software (SPSS Inc., Chicago, Illinois, USA). The different subgroups of surgeons and operating settings were analyzed. The correlations of the investigated complication parameters were statistically analyzed by Fisher's exact test and the chi-square test. Pre- and postoperative CT scans as imaging controls were obtained within the first 12 hours after surgery as a postoperative imaging control in every patient. All CT scans were performed on a 16 slice Siemens SOMATON® Sensation (Siemens AG, Erlangen, Germany) acquiring 4-mm axial slices. In case of hemorrhage or malplacement of the EVD, additional coronal and sagittal images were reconstructed. The CT scans were analyzed by independent physicians unaware of the clinical outcome in the Department of Neuroradiology of the University Hospital of Zurich, using standardized software (picture archiving and communication system).

Placement of the external catheter via ventriculostomy was performed by a standardized protocol,[7] which comprised fixed anatomical landmarks and was conducted by JRs under the guidance of SRs or ATs. The procedure for a right frontal approach was as follows. The patient was placed in the supine position, with the head elevated approximately 20°, prepared for surgery with a local shave, followed by disinfection following the usual practice. The correct placing position of the burr hole was verified by anatomical landmarks, as described in the literature and known as Kocher's point. The first landmark, situated approximately 13 cm posterior to the nasion, was measured to verify the coronary suture. Then, following the coronary suture, the right mediopupillar line was crossed after approximately 3 cm. Based on this point, the location for the burr hole was selected at 1–2 cm precoronally. The EVD placement was conducted orthogonally to the brain parenchyma and according to the coronal and sagittal planes, which include the ipsilateral medial canthus and the ipsilateral tragus, respectively. The optimal intraventricular endpoint was defined as in front of the ipsilateral foramen of Monroe,[1,7,15] and the maximum insertion depth of the catheter was 6–7 cm. The catheter was subcutaneously tunneled as far as possible from the skin incision,[14] and was connected to a standardized gravity-dependent drainage system. The procedure for the occipital approach used Frazier's point (7 cm above the inion and 3 cm lateral of the midline with an catheter insertion depth of 9 cm).[1,7]

Three different EVD catheters were utilized depending on the condition of the patient as follows. i) The Bactiseal™ EVD catheter (Codman, Raynham, Massachusetts, USA) with anti-microbial impregnation (clindamycin and rifampicin) was used in patients receiving a secondary placed EVD defined as any catheter exchange after primary placement, long-term ICU stay, and/or patients with any general infective condition. ii) The Neurovent® ventricular catheter (Raumedic Rehau AG, Münchberg, Germany) with an integrated intracranial pressure and temperature measurement was placed for special monitoring needs. iii) The standard ventricular catheter (Dispomedica, Hamburg, Germany) was utilized in other cases.

Results

Overall 137 EVD devices were placed including 99 primary placements (72%) and 38 secondary placements (28%), performed through a unilateral burr hole in 120 cases (88%) and bilateral burr hole trepanation in 17 (12%). Most of the EVD devices (n = 132, 96%) were placed frontally, whereas 5 (4%) were placed occipitally as frontal placement was not possible. Based on the admitting diagnosis, 72 standard EVD devices (53%), 52 Bactiseal EVD devices (38%), and 13 Neurovent EVD devices (9%) were implanted (Table 2).

The overall complication rate was 22 of 137 placements (16.1%), with malplacements in 3 cases (2.2%), hemorrhage complications in 5 cases (3.6%), and EVD-related infections in 14 patients (10.2%) (Table 3).

The three malplaced EVD devices were located ipsilateral in the thalamus, next to the internal capsule, and within the internal capsule (Table 3). Two of the three misplacements were performed in the OR by JRs, and the third at the bedside in the ICU by a SR (Tables 4 and 5). Replacement was performed without further complications in all three cases.

Hemorrhage related to ventricular catheter placement, with dimensions of 1 cm^3 to 5 cm^3, was detected in five cases (3.6%) on the ipsilateral placement side, one in the thalamus region, three following the trajectory line, and one next to the caudate nucleus (Table 3). Four (2.9%) of five hemorrhages were associated with EVD placement performed by JRs and

one by an AT (Table 4). One hemorrhage (0.7%, by JR) occurred in the OR and four (2.9%, 3 by JR and 1 by AT) in the ICU (Table 5). No operative evacuation of the hemorrhage was necessary.

Overall ventriculostomy-related infections in the postoperative course were detected in 14 of 137 cases (10.2%) with secondary infection in 7 of 38 cases (18.4%). Common bacterial agents such as *Staphylococcus aureus* coagulase-negative staphylococcus species or *Propionibacterium acnes* were identified by microbacterial examinations. Two of 14 infections were found in patients treated by JRs, and 12 infections in patients treated by SRs or ATs (6 each) (Table 4). Seven ventriculostomy-related infections occurred in patients who received the EVD placement in the OR, and 7 at the bedside in the ICU (Table 5). Infections occurred using standard EVD catheter and the Bactiseal EVD catheter in 7 cases each (Table 6).

Statistical analysis of the data showed no significant correlations regarding the rates of infection, malplacement, or hemorrhage in the subgroups of different surgeons, operation settings, or catheter use. The p values ranged between 0.13–0.99 (Tables 4–6).

Table 2 Characteristics of operation procedures (137 placements in 120 procedures)

Characteristics	Number	%
Side of placement (n = 137)		
unilateral	120	87.6
bilateral	17	12.4
Site of placement (n = 137)		
frontal	132	96.4
occipital	5	3.6
Time of placement (n = 137)		
primary	99	72.3
secondary	38	27.7
Operating room (n = 120)		
operating room	54	45.0
intensive care unit	64	53.3
trauma room	1	0.8
general ward	1	0.8
Surgeon (n = 120)		
junior resident	56	46.7
senior resident	42	35.0
attending	39	32.5
EVD device (n = 137)		
standard EVD	72	52.5
Bactiseal® EVD	52	37.9
Neurovent® EVD	13	9.5
Imaging (n = 120)		
postoperative CT within 24 hrs	120	100

EVD: external ventricular drainage.

Discussion

Complications related to EVD are well known[2,8,10–13,15,18,20] and many studies have been published measuring different complication rates (Table 1). Beside

Table 3 Overall complications (22 of 137 placements, 16.1%)

Overall complications	Number	%
Hemorrhage	5	3.6
thalamus	1	0.7
trajectory line	3	2.2
caudate nucleus	1	0.7
Infection	14	10.2
Malplacement	3	2.2
thalamus	1	0.7
next to internal capsule	1	0.7
internal capsule	1	0.7

Table 4 Complications and surgeon experience

Complications	Surgeons	Number	%
Overall complications (p = 0.918)	junior resident (n = 56)	8	14.3
	senior resident (n = 42)	7	16.6
	attending (n = 39)	7	17.9
Hemorrhage (p = 0.183)	junior resident	4	7.1
	senior resident	0	0.0
	attending	1	2.6
Infection (p = 0.140)	junior resident	2	3.7
	senior resident	6	14.3
	attending	6	15.4
Malplacement (p = 0.782)	junior resident	2	3.6
	senior resident	1	2.4
	attending	0	0.0

Table 5 Complications and surgical setting

Complications	Surgical setting	Number	%
Overall complications (p = 0.841)	operating room (n = 54)	10	18.5
	intensive care unit (n = 64)	12	18.7
Hemorrhage (p = 0.255)	operating room	1	1.8
	intensive care unit	4	6.2
Infection (p = 0.491)	operating room	7	12.9
	intensive care unit	7	10.9
Malplacement (p = 0.444)	operating room	2	3.7
	intensive care unit	1	1.6

Table 6 Complications and external ventricular drainage (EVD) device

Complications	EVD device	Number	%
Overall complications (p = 0.708)	standard EVD (n = 72)	13	18.0
	Bactiseal® EVD (n = 52)	8	15.4
	Neurovent® EVD (n = 13)	1	7.7
Hemorrhage (p = 0.131)	standard EVD	4	5.6
	Bactiseal® EVD	0	0.0
	Neurovent® EVD	1	7.7
Infection (p = 0.402)	standard EVD	7	9.7
	Bactiseal® EVD	7	13.5
	Neurovent® EVD	0	0.0
Malplacement (p = 0.999)	standard EVD	2	2.8
	Bactiseal® EVD	1	1.9
	Neurovent® EVD	0	0.0

procedure-related complications such as catheter malplacements or hemorrhages along the trajectory line, ventriculostomy-related infection risk is the most common EVD complication.[2,8,10–13,15,18,20] However, data has been insufficiently analyzed regarding iatrogenic factors that may influence or bias the EVD placement. In daily clinical practice, the environment of the operative treatment as well as the educational level of the surgeon are important factors when analyzing EVD-related complications and need to be kept in mind. Furthermore, this neurosurgical procedure is not only performed by neurosurgeons but also by neurointensivists, and showed a higher overall complication rate in the 29 reported EVD placements[5] compared to other studies (Table 1). In our study, the overall complication rate of 16.1% evaluated in 137 EVD placements fits into the lower median of the literature (Table 1), and is lower compared to EVD studies performed by non-neurosurgical physicians.[5] One reason for our results might be found in the institutional standardized surgical protocol with qualified staff neurosurgeons supervising inexperienced residents. To reveal the specific iatrogenic related influences in the EVD placement due to the educational level of the performing neurosurgeon or the operation setting, we took a closer look at the perioperative complications in detail.

Looking at the complication rate depending on the performing surgeon, more complications during the surgical procedure (malplacement or hemorrhage) could be found with JRs. The more experienced the surgeon, the fewer perioperative complications occurred in this study. In contrast, more ventriculostomy-related infections could be detected in patients treated by more experienced neurosurgeons (SR, AT). An explanation for this could be found in the initial physical condition of the patient. In demanding patient situations the EVD placement was performed by an experienced neurosurgeon and thus introduced bias into the analysis of this study. Therefore, this led to a higher risk of ventriculostomy-related infection complications. There were no statistically significant higher rates of malplacements, infections, or hemorrhages any group of the performing surgeons (p values 0.14–0.78). In contrast to our results, a previous study reported no differences in the coherence of malplacement or hemorrhage depending on the educational level of the neurosurgeon.[12]

Differences in complication rates, especially the risk of ventriculostomy-related infection, could not be observed with the operation setting. These findings could be explained by the similar surgical time period in the OR and bedside at the ICU as well as the standardized operation protocol. Our results authenticate the previous hypothesis that this external factor does not bias the perioperative EVD complication rate.[12,17] There were no statistically significant higher complication rates such as malplacement, infection, or hemorrhage in the different operation settings (p values 0.26–0.49).

Malplacement and bleeding associated with EVD placements can lead to severe clinical complications for the patient. Drainage devices with more than 8-cm insertion depth have a higher risk for iatrogenic complications.[15,18] In our standardized protocol, the maximal insertion depth was 6 cm. Malplacement during the EVD procedure is a commonly described complication,[6,16] although previously published studies do not analyze the causes in full detail. In particular, notes or details on iatrogenic influence factors have been missing (Table 1). Our 2.2% complication rate is in the lower range compared to other studies.

The incidence of hemorrhage during or after EVD placements is one of the major and even life-threatening complications (Table 1). Compared to previously published studies showing a range of perioperative hemorrhage complications between 1.9% to 41%, the hemorrhage complication rate of 4% represents a tolerable and arguable result (Table 1). A possible pitfall, which could be stated as a reason for this wide range of complication rates, is that there is no integrative and specific method established to analyze and report the hemorrhage size. A hemorrhage size between 1 cm^3 to 5 cm^3 is reported as the significant clinical threshold point[6,15] and was used for the analysis model in this study. Smaller lesions especially punctuate hemorrhage after EVD placements were not included in this rate. However, none of the patients with such a lesion showed clinically measurable deficits in our study. Further detailed studies or even a score to quantify the perioperative hemorrhage could be of major interest.

CSF infection rates after EVD placements range up to 20% and are listed as the most common complications in the perioperative clinical course (Table 1).[1,3,5,8,10,14,19,21] In coherence with the admitting diagnosis followed by operative intervention and an extended ICU abidance, these factors can be assumed to increase the risk of ventriculostomy-related infection. Our results showed that the ventriculostomy-related infection rate was significantly higher in secondary EVD placements compared to primary procedures. According to the surgical setting, no preference could not be found with the same ventriculostomy-related infection risks in the OR compared to the ICU. However, taking a closer look at the educational level of the performing surgeon, differences could be detected with a higher ventriculostomy-related infection rate with more experienced surgeons compared to JRs, probably because experienced neurosurgeons are more likely perform EVD placements on patients, who are in more critical conditions with higher infection risk compared to the patients treated by JRs. Seven cases of ventriculostomy-related infection were detected among the 72 surgeries using standard EVDs, and seven cases among the 52 surgeries using Bactiseal EVDs. Although the statistical analyses were not significant, these results assume that patients with high infection risk in general obtained benefit from the anti-microbial impregnated catheter. Our results are in agreement with the infection rate of 11% associated with significant differences using EVD devices with antimicrobial impregnated surface.[21] In general, no statistically significant higher rate of ventriculostomy-related infections was found in any of the operation settings (ICU, operation theater), in the different groups of surgeons, or the different catheters used (p values 0.13–0.99).

Since all patients with high infection risk were treated with a Bactiseal EVD in this study to avoid further complications, no statements regarding the outcome of high infection risk patients with standard EVDs could be obtained and may bias our results. However, previous studies showed that these antibiotic impregnated EVDs are superior compared to standard EVDs in this high risk patient subgroup.[8,10,14,19,21] Therefore, based on this knowledge, we decided to use only Bactiseal EVDs in these patients to guarantee the best patient outcome.

Complications related to EVD are common and can be influenced by external or iatrogenic factors. Surgery setting had no influence on the complication rate, but lower educational level of the surgeon was associated with higher complication rate of the EVD placement. Ventriculostomy-related infections were more likely in secondary EVD placements and patients treated by ATs. Further prospective studies are needed to evaluate the statistical impact of our observations and to improve the complication rate of this procedure in the future with a well-established conformed methodology.

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Address reprint requests to: Christoph M. Woernle, MD, Department of Neurosurgery, University Hospital Zurich, Frauenklinikstr. 10, 8091 Zurich, Switzerland.
e-mail: c.woernle@gmail.com